Lederberg

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Mr. Oran W. Nicks, Director
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National Aeronautics and Space Administration
1520 H Street, Northwest
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Dear Mr. Nicks:

Subject: Summary of Spacecraft Sterilization Program

I. Origin of the Sterilization Requirement

In April 1958, the International Council of Scientific Unions, (ICSU), set up an ad hoc committee to consider the possible effect of the chemical and biological contamination of extra-terrestrial bodies by space probes. The CETEX, (Committee on Contamination by Extraterrestrial Exploration), decided that early landings of spacecraft on the moon or planets might seriously interfere with subsequent research and suggested that an internationally recognized code of conduct be established to minimize extra-terrestrial contamination. The committee recognized that risks must be taken but recommended that they should be made as small as possible. Special concern was expressed over biological contamination in the form of terrestrial microorganisms and advised that a study of the problem of spacecraft sterilization be immediately undertaken.

The Westex committee, (Committee on Exobiology), of the Space Science Board of the National Academy of Sciences and the NRC-Armed Forces Bioastronautics Committee also deliberated on the problem of biological contamination and expressed deep concern over the possible damage to biological investigations on extra-terrestrial bodies by inadvertantly seeding them with terrestrial organisms. As a result, both committees recommended to the NASA that immediate steps be taken to implement a study to develop spacecraft decontamination procedures.

In October 1959, the NASA adopted a policy initiating a program for the study and application of methods for the biological decontamination of all spacecraft having a probability of impacting or landing on the moon or planets. Chief responsibility for this program was delegated to the Jet Propulsion Laboratory, California Institute of Technology.

II. The Problem of Spacecraft Sterilization

The problem of extra-terrestrial contamination must be considered for three types of missions: 1) the fly-by, in which the spacecraft approaches the planet sufficiently close to make worthwhile observations, 2) the orbiting vehicle, 3) the lander. The fly-by spacecraft need not be subjected to direct sterilization procedures if its trajectory is calculated for very low probability of impact. Anticipated fly-by missions in the current U.S. space exploration program assumes safe, non-impact trajectories so that no spacecraft sterilization requirement is necessary. Spacecraft which are to be put into orbit around a planet must undergo a sterilization treatment, since the probability of accidental impact will be relatively high. Likewise, all landers must be sterilized.

Consideration must also be given to possible impact of the final stage boost vehicles which have a high chance of impacting the extra-terrestrial bodies along with the spacecraft. Such vehicles will be prevented from impacting by including a retro-rocket on the booster to deflect it from an impact trajectory after separation from the spacecraft.

The application of biological decontamination techniques to spacecraft presents a number of very difficult problems. Since biological sterility is defined as the complete absence of living or viable organisms, the objective of spacecraft sterilization is to achieve biological sterility to a very high degree of probability. In order to accomplish this it is necessary to apply sufficiently powerful sterilizing methods to destroy viable microorganisms without degrading the functional performance of the spacecraft. This is the crux of the spacecraft sterilization problem. Another serious difficulty involves the integration of these methods into very complex assembly, test, and operational procedures which usually must be performed under a very close schedule. No method of sterilization exists which is not time consuming and which does not require some skill and careful control in application. Therefore, sterilization

imposes a severe burden on the engineering schedule and the engineering groups responsible for the preparation and flight of the spacecraft.

The solutions to these general problems requires time, money, and much effort. Time is required to develop spacecraft hardware that is durable to sterilization methods and to develop improved sterilization techniques and procedures which will reduce the effects on engineering schedules and hardware. Under the conditions of the present accelerated space program, research and development in this area is a problem in itself particularly because of time limitations.

III. Status of U. S. Sterilization Program

The current procedures include methods to destroy microorganisms that may have become imbedded in plastic materials or electronic components, methods to sterilize the surfaces which are mated during the assembly procedure, methods to decontaminate all externally exposed surfaces of the assembled spacecraft, and methods to maintain the sterility of the spacecraft after the final sterilization operation.

To ensure that plastic materials and electronic components are free of viable microorganisms, all materials, components and sub-systems which are not degraded by thermal exposure are subjected to a dry heat sterilization cycle of 125°C for 24 hours. If a sub-system contains one or more components which will not endure the thermal exposure, it is first heated without the heat sensitive elements. The sensitive element is separately sterilized by other methods such as radiation exposure or sterile fabrication. In a very small number of cases, neither heat, radiation, or sterile fabrication is possible. The sensitive component is then added to the heat sterilized sub-system by sterile assembly procedures. This requires placing the sub-assembly and the component in a suitable transparent isolator which permits a technician to perform the assembly with rubber gloves sealed to holes in the wall of the box. The surfaces of all materials are sterilized just prior to assembly by a sterilizing gas. The component is then added to the subsystem under completely sterile conditions.

Surfaces that are mated during the assembly procedure are thoroughly scrubbed with isopropyl alcohol before joining them together. However, much more powerful liquid sterilizing agents are under study which will be available in the near future.

After the conclusion of the assembly and test operations, all exposed surfaces of the spacecraft are subjected to a sterilizing gas mixture composed of 12 per cent ethylene oxide and 88 per cent Freon-12, for 11 hours, at 35 to 45 per cent relative humidity and at room temperature. This operation is performed by placing the spacecraft within a chamber consisting of the vehicle nose cone which has been designed with sufficient sealing to function as a gassing chamber and as a protection against decontamination after sterilization. The nose cone is not removed until the spacecraft is ejected beyond the atmosphere of the earth.

Using the above methods, the present sterilization procedure for lunar spacecraft consists of first heating the largest sub-assemblies consisting with the number of heat sensitive parts in the system. Heat sensitive components are then added to the sub-assemblies by sterile assembly techniques. Sub-assemblies are then fitted together using liquid sterilants to sterilize mating surfaces before joining. After final test operations are performed, the spacecraft is exposed to the sterilizing gas mixture for eleven hours after which the gas is purged from the chamber with nitrogen sterilized by passage through a bacteriological filter. The spacecraft is thereafter protected from further contamination during field operations and launch.

Although the current sterilization procedures are considered adequate for the early lunar missions, more stringent methods are being contemplated for future planetary spacecraft.

Current studies have shown that the dry heat sterilization cycle of 125 degrees centigrade for 24 hours appears to be adequate for destroying organisms deeply imbedded in plastics and electronic components. However, further studies will be made to assure that this technique is entirely adequate in all cases, or whether longer times and higher temperatures will be required to sterilize with certainty.

The use of liquid sterilants in assembly operations is considered undesirable for planetary spacecraft sterilization or whenever the highest degree of decontamination is required. It is intended that the use of this method will be minimized. The use of liquid sterilants involves hundreds of individual sterilizing operations and consequently reduces the certainty of sterility due to the chances of errors in application. In cases where they must be used, it will be necessary to enforce strict control over the procedure. Although gaseous sterilization is one of the best available methods, it is time consuming and will not penetrate deep into materials to sterilize imbedded microorganisms.

The present thinking on achieving highly efficient decontamination involves the concept of thermal sterilization of the completely assembled spacecraft under a sealed nose cone or shroud. Under these conditions, both surface and internal sterilization could be performed simultaneously. This technique would greatly increase the probability of achieving complete biological decontamination of the spacecraft by reducing the procedure to a single, controlled operation, instead of many operations. It would relieve the engineering groups of the responsibility of integrating sterilization into each individual sub-system assembly and testing procedure, and would reduce the decontamination process to the minimum of operational complexity.

However, in order to accomplish this objective a considerably large engineering effort will be involved in order to develop a spacecraft system composed completely of thermally stable elements. In existing lunar spacecraft an estimated 99 percent of the electronic components can survive and function after the heat sterilization cycle. Many of the components are designed to operate at high temperatures without special fabrication. At least 99 per cent of the plastic materials included in these spacecraft will also endure this cycle. Efforts are being made to initiate hardware development in a few areas that will not permit sterilization by heat. The most important heat sensitive components are batteries, solid propellants, transistors and diodes, magnetic tapes, and pyrotechnic actuators. Although the relative number of thermally sensitive devices is small, the engineering effort required to replace them with stable devices will be large.

Other problem areas which will be investigated are the long term effects of the heat cycle on components, i.e., effects on the expected life of the component after heating, and the effects on system calibration, because with a final thermal sterilization technique, systems that have drifted out of calibration cannot be directly recalibrated.

IV. Evaluation of the Sterilization Requirements

Because of the hardship introduced into the engineering phases of the national space program, and the high cost in dollars and man hours, which are implied in the sterilization requirements, consideration of the necessity of this requirement should be made.

The scientific value of the sterilization program is undeniable despite objections to the contrary by one or two reputable scientists. The essence for the defence of spacecraft sterilization rests in the fact that no direct knowledge is available about the surface environments of extra-terrestrial bodies, regardless of the theoretical considerations upon which the importance of sterilization is denied. The possibilities which concern reputable biologists do exist, and it will be impossible to determine if there really is a sterilization problem until actual observations are obtained at the surface of these bodies. Early space probe experiments should be designed to do this. Due to the extreme importance that information on extra-terrestrial biology would have on understanding the nature and origin of life, and the fact that a single space probe bearing a single viable microorganism could potentially destroy forever, the validity of this information, the sterilization of such spacecraft seems necessary from a moral and political standpoint as well as a scientific one.

However, reasonable risks will be necessary because it will be impossible to land on the moon or the planets without some chance of introducing a biological contaminate. No method is perfect no matter how well thought out and tested. Nevertheless, our methods should be made as perfect as possible so that every reasonable precaution will have been taken to ensure the integrity of our studies.

Even though detailed knowledge of the lunar surface is small, knowledge about the atmosphere, surface temperatures and ultra-violet radiation levels are known to a high degree of confidence. On the basis of this knowledge, most biologists agree that risks to scientific exploration are not dangerously high if sufficiently small amounts of biological material were accidentally landed on the moon. Microorganisms landed on the lunar surface would not be expected to grow because of the lack of water, nor would they survive for long because of the intense ultraviolet radiation striking the surface and the high surface temperatures. However, microorganisms which were imbedded beneath a layer of dust would be protected against both ultraviolet and high temperatures. Under these conditions some microorganisms might be expected to survive in a dormant state for very long periods of time. The only danger to subsequent investigations would be in the re-detection of these dormant contaminants. If such contaminants were kept very small and confined to small areas of

the moon's surface, the probability of detecting them at a later time would be insignificant. Nevertheless, strict requirements for keeping the contamination of the moon to an absolute minimum has important side benefits. Efforts to decontaminate lunar spacecraft are important in developing sterilization techniques of the highest efficiency for planetary missions.

The sterilization requirements for the planets, however, should be made as stringent as possible. While recent temperature measurements on the surface of Venus indicate temperature incompatible with the existence of any known form of terrestrial life, there is yet some uncertainty about the observations. Several kinds of observations are indicative of an endogenous Martian biology which will be important to protect from contaminated spacecraft. Also, our current knowledge of Mars indicates that some form of terrestrial microorganisms might be active if landed. The validity of this can only be determined by a closer examination of the planet.

The cost of sterilization in dollars and cents, is trivial compared with the total space budget. The cost in time spent on special engineering problems appears fairly large. However, the development of heat sterilizable spacecraft could produce important incidental benefits. Such spacecraft would undoubtedly have increased reliability, and would be considerably more durable to the space environment. In the long term this could advance spacecraft technology significantly.

The time and money expended in spacecraft sterilization must be considered an investment. If sterilization proves to be necessary it will have been worth all of the time, money and effort. If it proves unnecessary we will have obtained some side benefits and the assurance that we have conscientiously performed our duty to science and society.

However, if we do not exert serious efforts in this area, and it turns out to have been necessary after all, we may be in the position of having destroyed the most significant scientific discoveries in human history.

V. Summary

The most reputable national and international scientific organizations have recommended that sterilization of spacecraft be made an important part of the space exploration

program. In response to these recommendations the NASA has initiated the study and execution of a program to decontaminate all lunar and planetary spacecraft. Difficult engineering and biological problems are involved in the execution of this program including the development of effective sterilization methods, and the development of methods for integrating the engineering and the sterilization procedures. Very good progress has been made in sterilizing early lunar spacecraft using heat to sterilize electronic components and materials, liquids to sterilize surfaces during assembly, and ethylene oxide gas mixtures for the final sterilization of the surfaces of the completely assembled spacecraft. Efforts are being made to simplify procedures and increase the effectiveness of sterization methods for future spacecraft. Such efforts, although expensive in the absolute sense cost little in terms of the total space budget and the moral, political and scientific obligations to future generations.

Sincerely yours,

JET PROPULSION LABORATORY

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